FINAL REPORT

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DEMONSTRATING OPPORTUNITIES FOR HOG MANURE FERTILIZER IN THE GRAY SOIL ZONE

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Final Report

Demonstrating Opportunities For Hog Manure Fertilizer in the Gray Soil Zone

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1. Summary

The objective of this project was to demonstrate the annual crop response of various application rates of swine manure injection compared to commercial fertilizer and monitor the effects of swine manure on the environment in the gray soil zones.

Sites were selected on gray wooded soils in the fall of 1999 at the Agriculture and Agri-Food Canada research site at Loon Lake in northwest Saskatchewan and east of Melfort for the project. Swine manure was injected at both sites with the PAMI low disturbance manure injection system at application rates of 3,000, 6,000, and 9,000 gpa (33,900, 67,800, and 101,700 L/ha). Spring soil tests confirmed increased available soil inorganic N corresponding to application.

In spring of 2000, the Melfort site was seeded to spring wheat. In contrast, the manure plots were split into three longitudinal sections at Loon Lake and seeded to canola, pea, and barley in spring of 2000.

At Melfort, the addition of swine manure and urea both significantly increased grain yield with a doubling of the yield at 9,000 gpa (101,700 L/ha) compared to the check. At Loon Lake, the addition of swine manure resulted in significantly higher canola and barley yields with more than double canola yields and more than quadruple the barley yields compared to the check. Pea yield did not significantly increase with the addition of manure due to the pea's ability to fix Nitrogen (N).

The new PAMI swine manure injector truck was used to low disturbance inject the 3,000 gpa (33,900 L/ha) treatment in Fall 2000 and 3,000 gpa (33,900 L/ha) and 6,000 gpa (67,800 L/ha) treatments in Fall 2001.

In spring 2001, the Melfort site was seeded to canola. The second year application of 3,000 gpa (33,900 L/ha) produced the highest yield (36 bu/ac versus 21 bu/ac) (2,016 kg/ha versus 1,176 kg/ha) compared to the check. Results from the plots with 6,000 and 9,000 gpa (67,800 and 101,700 L/ha) injection in Year 1 was little different than the check, so there was no evidence of N carryover affecting yield. Severe symptoms of nitrogen induced sulfur deficiency affected yields in the urea plots and in the 6,000 and 9,000 gpa (67,800 and 101,700 L/ha) single application plots. Fall 2001 residual N levels were low.

At the Loon Lake site, in Spring 2001, available N in the soil profile followed the pattern of manure injection. The site was seeded to flax, pea, and barley crops. Yields were generally lower due to drought. Pea showed a small but non-significant response to the second year of the low rate, but there was no apparent response to the 6,000 and 9,000 gpa (67,800 and 101,700 L/ha) for Year 1 residual. Manure and urea increased N uptake and sulfur concentration in the grain. Barley responded significantly in grain yield to the second 3,000 gpa (33,900 L/ha) application with a yield increase of 20.5 bu/ac (1,100 kg/ha). The residual affect of the year 1, 6,000 and 9,000 gpa (67,800 and 101,700 L/ha) applications, produced a similar yield increase, which is evidence of carryover of N in this case. Protein in barley significantly increased (10 to 12.5%) and the sulfur in the grain also increased with manure application. Flax yields were low and were increased by manure and urea, but only the straw yield was significantly increased.

In spring 2002, the Melfort site was seeded to oat and the Loon Lake site was seeded in rotation to canola, pea and barley.

Oat yield was significantly increased by swine manure and urea. However, higher manure application rates did not increase yields beyond the baseline rate, likely due to drought stress at that site. There was very little effect on oat protein due to manure or urea at Melfort in 2002.

Severe drought at Loon Lake resulted in complete crop failure in 2002.

In conclusion, annual applications of swine manure at rates of approximately 3,000 gallons per acre (approximately 100 kg N/ha) produced good yield responses on these Dark Gray Luvisolic soils, with no evidence of nutrient loading or deep migration by leaching. Larger single applications intended to last two or three years appear to be less effective on these soils, with less residual effect possibly due to immobilization of N in the soil organic matter or some unaccounted for N loss. To achieve optimum production on soils such as these, the application of supplemental sulfur fertilizer would be recommended to account for the low amount of sulfur added relative to nitrogen in the swine manure.

2. Background and Objectives

While there is considerable demonstration and research work underway looking at soil and crop response to swine manure in the Brown, Dark Brown, and Black soil zones of Saskatchewan, little attention has been given to the Gray soil zones. Soils in the Gray zone are very different from soils in the Brown, Dark Brown, and Black zones having been developed under forest as opposed to grassland. Gray soils are highly leached with low levels of organic matter and frequently suffer from deficiencies of micronutrients, as well as N, P, K, and S. Manure application to these soils may have particular benefit, as these soils often have multi-element fertilizer recommendations and swine manure contains a mixture of both macro and micronutrients.

The intent of the project was to complement the swine manure demonstration/research projects already in progress in other soil zones.

3. Project Description

PAMI, Agriculture and Agri-Food Canada, and Soil Science, University of Saskatchewan jointly conducted this project.

Two sites in annual crop production in the Gray soil zone were selected for the project in fall of 1999. The first site is located 3.4 mi (5.5 km) east of the Melfort Research station while the second site is located at the Agriculture and Agri-Food Canada research site near Loon Lake. The research site is 2 mi (3.2 km) east and 2 mi (3.2 km) north of the village of Loon Lake.

The PAMI 10 ft (3.0 m) wide, low disturbance injection system was used for the manure application of the plots in fall of 1999. Modified Bourgault mid-row coulters on 1 ft (30 cm) row space were attached to a 10 ft (3.0 m) wide cultivator frame that was towed behind the 1,200 Imperial gallon (5,448 L) pressure tank (**Figure 1**).

Figure 1. PAMI Injector.

The Bourgault mid-row coulters were modified by replacing the stock spring with a spring with 50% higher trip force (**Figure 2**).

Figure 2. Modified Bourgault Mid-Row Coulter.

In addition, a modification was made to the fertilizer delivery boot to facilitate the delivery of high volumes of liquid manure. Extra weight was added to the cultivator frame to bring the average force/coulter to 400 lb (181 kg). The heavier spring and weighted cultivator improved coulter penetration in hard soil conditions.

Hog manure was trucked to the sites from nearby hog operations using a septic tank truck system. Each load was sampled and the sample forwarded to Soil Science for nutrient analysis.

In fall of 2000 and 2001, the tractor/pressure tank/toolbar was replaced with the new manure injector truck (**Figure 3**).

Figure 3. PAMI Manure Injector Truck.

The truck is equipped with a mounted, parallel link, three-rank toolbar that can be configured with low disturbance disc coulters or shanks with sweeps or spikes. For this experiment, the toolbar was equipped with modified Bourgault mid-row coulters described previously.

A randomized complete block design with four replicates was used at both sites. Plot dimensions were 10 ft x 100 ft (3 m x 30.5 m) at Melfort and 20 ft x 100 ft (6.1 m x 30.5 m) at Loon Lake. Swine manure was injected in Fall 1999 at rates of 3,000, 6,000, and 9,000 gpa (33,900, 67,800, and 101,700 L/ha) to provide approximately 50, 100, and 150 lb/ac (56, 112, and 168 kg/ha) of available N. Total N injected is about twice these rates with the assumption that half the N is plant available in the first year. In fall of 2000, the swine manure was injected at 3,000 gpa (33,900 L/ha). The sequence of treatments for the three application years is shown in **Table 1**. This was revised in 2001 because the 9,000 gpa (101,700 L/ha) application should not be reapplied in 2001.

Table 1. Revised Sequence of Treatments Applied.

Treatment	Fall 1999	Fall 2000	Fall 2001	Fall 2002[1]
1	Check	Check	Check	Check
2	3,000 gpa	3,000 gpa	3,000 gpa	3,000 gpa
3	6,000 gpa	No application	6,000 gpa	No application
4	9,000 gpa	No application	No application	9,000 gpa
5	Soil Test Urea	Soil Test Urea	Soil Test Urea	Soil Test Urea

[1] New funding has been secured from ADF and Sask Pork to continue the Melfort, but not the Loon Lake site.

Manure was applied on October 14, 1999, October 23, 2000, October 17, 2001 and October 23, 2002, at Melfort with an injection depth averaging 3 in (7.6 cm) in 1999, 4.5 in (11.4 cm) in 2000, 4 in (10 cm) in 2001, and 4.5 in (11.4 cm) in 2002. At Loon Lake, the swine manure was applied on October 20, 1999, October 24, 2000, and October 18, 2001 at an average injection depth of 5 in (12.7 cm) in 1999 and 2000, but a 4 in (10 cm) depth in 2001. Manure samples were taken from each load of liquid manure for later nutrient analysis. Actual rates of nutrient application will be calculated on the basis of the lab analysis.

Agriculture and Agri-Food Canada seeded and harvested the plots in spring and fall of 2000, 2001, and 2002.

Tours were conducted at the Loon Lake site in Summer 2000, 2001, and 2002 with 28,15, and 20 participants. As part of the Melfort Research Station field day, 15 farmers toured the site in 2001 and 18 farmers in 2002.

4. Results and Discussion

At the Melfort site in the fall of 1999, there was a problem with penetration of the coulter discs into the dry soil. At this site the discs were able to penetrate to about 3 in (7.6 cm) and at that depth a hardpan was hit resulting in lifting the machine partly out of the ground (**Figure 4**). Target penetration depth was 4.75 to 5 in (12 to 12.7 cm). The injection toolbar was weighted to 400 lb/coulter (181 kg) and this weight in most soil conditions results in adequate penetration.

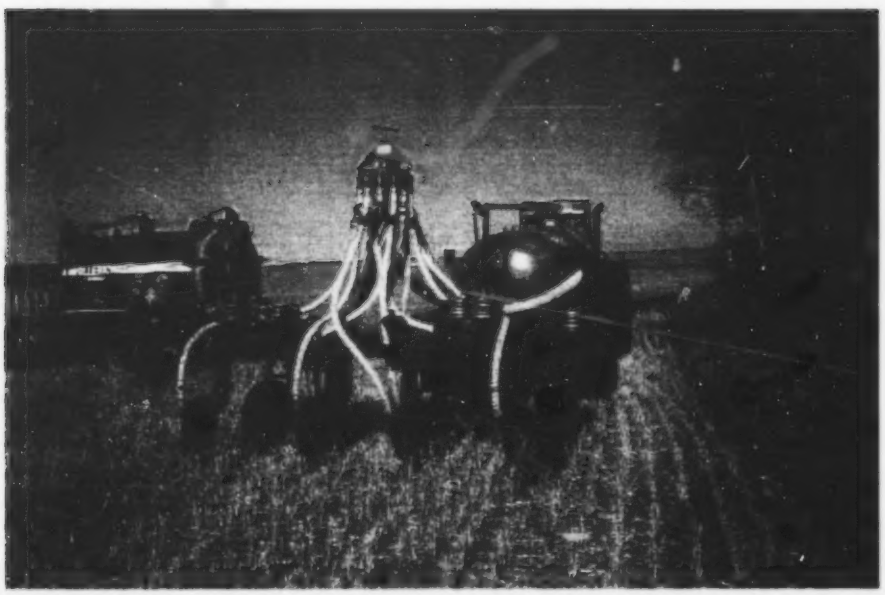

Figure 4. Poor Penetration due to Hardpan in 1999 at Melfort.

Dr. Jeff Schoenau attributes the hard soil conditions to a plow pan or Bt horizon that has been exposed to the surface by erosion. The penetration problem that occurred in 1999 was not repeated in fall of 2000, 2001, and 2002. Soil conditions were dry in Fall 2000 and Fall 2001, but higher down force with the new truck injector resulted in injection depth averaging 4.5 in (11.4 cm) (**Figure 5**). There were no soil penetration problems in Fall 2002 with an average injection depth of 4.5 in (11.4 cm).

Figure 5. Good Injection in Dry Conditions, in 2000, with use of the PAMI Manure Truck.

The lack of coulter penetration in 1999 resulted in about 10% of the surface covered with swine manure at the 9,000 gpa (101,700 L/ha) application rate. At 3,000 and 6,000 gpa (33,900 and 67,800 L/ha) all swine manure was contained in the coulter furrow. In 2000, the manure was only applied at 3,000 gpa (33,900 L/ha) and it was contained completely within the coulter furrow. In 2001 the soil condition was dry, but the 3,000 gpa (33,900 L/ha) rate was contained in the furrow and all but approximately 5% of the 6,000 gpa (67,800 L/ha) rate. Injection depth was 4 in (10cm). Trash from the plot combine was left down the center of plots (**Figure 6**). The worst piles were spread and the others were injected through successfully (**Figure 7** and **8**). In Fall 2002 the swine manure was contained within the furrow at all injections rates.

Figure 6. Trash Before Injection.

Figure 7. Successful Injection Through Residue in 2001.

Figure 8. Melfort Injection at 6,000 gpa (67,800 L/ha), in 2001, Showing Slight Surface Residue.

Soil conditions were dry at the Loon Lake site in fall of 1999, 2000, and 2001. In fall of 1999, the coulters penetrated to 5 in (12.7 cm) in depth resulting in excellent injection efficiency (no manure on the soil surface) at all three application rates (**Figure 9**).

Figure 9. Excellent Injection Depth.

Penetration was similar in fall of 2000 and the 3,000 gpa (33,900 L/ha) treatment was contained completely within the coulter furrow. In Fall 2001, the coulters injected the swine manure at a depth of 4 in (10 cm). At 3,000 gpa (33,900 L/ha) all manure was contained in the furrow. In contrast, at 6,000 gpa (67,800 L/ha), the furrows were filled and up to 40% of the plot surface area was wet with swine manure following injection (**Figure 10**).

Figure 10. Loon Lake Injection 2001, Open Furrows with Liquid Showing.

The check treatments at both sites were not correctly applied in fall of 1999. The methodology required the manure injector to be run through one check treatment without applying swine manure. This treatment application was omitted so the check became an undisturbed check. All of the other treatments were injected with very little soil disturbance. It is unlikely that there will be a difference in results between a disturbed and undisturbed check. In Fall 2000 and 2001, the checks were correctly applied by running the coulters (without manure) through the check plots at a depth of 4.5 to 5 in (11.4 to 12.7 cm).

Agriculture and Agri-Food Canada seeded, maintained, and harvested the plots at both sites. Dr. Jeff Schoenau provided analysis of data and soil test results.

4.1 Melfort Result Analysis as Provided by Dr. Schoenau

4.1.1 2000 Results

Manure analysis from Fall 1999 treatments (**Appendix I**) indicated manure N application rates of 65 lb N/ac (73 kg N/ha) at 3,000 gpa (33,900 L/ha), 130 lb N/ac (146 kg N/ha) at 6,000 gpa (67,800 L/ha), and 195 lb N/ac (218 kg N/ha) at 9,000 gpa (101,700 L/ha).

Spring 2000 available N was quite high at 58 lb N/ac (65 kg N/ha) at the 0 to 24 in (0 to 60 cm) depth. Manure application increased spring available N, but was quite variable. Available P and K was essentially unaffected by manure application. However, P added, as manure was low, since the P content of the manure was low.

Hog manure application significantly increased wheat grain yield from 16.3 bu/ac (1,095 g/ha) in the check to 28.9 bu/ac (1,944 kg/ha) at 3,000 gpa (33,900 L/ha), 35.7 bu/ac (2,400 kg/ha) at 6,000 gpa (67,800 L/ha) to 39.7 bu/ac (2,670 kg/ha) at 9,000 gpa (**Appendix II**). Urea produced nearly equivalent yield response to manure. Overall, there was a very good grain yield response to hog manure with more than double the yield compared to the check. Protein was not greatly affected by manure. Other nutrients besides N in the manure may also be contributing to the yield response.

Soil available N in fall of 2000 was not significantly affected by manure or urea application. At this site there was a relatively high available N (ammonium and nitrate) yet a good yield response. Available N amounts do not appear to be a very good predictor of response to manure at this site. However, the N in the manure must be the major factor for yield increase since there was a good response to urea. Nitrogen applied to this soil may have been immobilized and released, due to high organic matter content and high microbial activity.

4.1.2 2001 Results

The 2000 soil nutrient data has been statistically analyzed again for this site. There was an error in the plot sequence that was used in sampling. The data now indicates the expected trend in that increasing rate of manure applied in the fall of 1999, produced significantly higher soil inorganic N in the spring of 2000. In line with this, yield and protein content of spring wheat at Melfort was significantly increased by manure application. Between 3,000 and 6,000 gpa (33,900 and 67,800 L/ha) rate at 58 to 107 lb N/ac (65 to 120 kg N/ha) would be optimal, based on 2000 data.

Spring Available Nutrients: Available N was the highest in the low rate 3,000 gpa (33,900 L/ha) repeated for 2000 and again in 2001, with 103 lb N/ac (115 kg N/ha) 0 to 24 in (0 to 60 cm) compared to 48 lb N/ac (54 kg/ha) in the control and about 63 lb N/ac (70 kg N/ha) in the single application at medium rate 6,000 gpa (67,800 L/ha) and high rate 9,000 gpa (101,700 L/ha) made once in 2000. Overall, there was not a lot of residual soil N carried over from 2000, even in the 6,000 and 9,000 gpa (67,800 and 101,700 L/ha) treatments. The pH was not significantly affected, but electrical conductivity (E.C.) was slightly, but significantly, elevated by the repeat low rate application made for 2001. Soil sulfate was elevated, but not significantly, by the manure application. Extractable K was lowest in the high manure application rate, which is unusual. As in 2000, there was no significant effect on extractable P. In fact, extractable P was lower in manured treatments **(Appendix III).**

Application of swine effluent for the second year at 3,000 gpa (33,900 L/ha) produced the highest canola yield at 36 bu/ac versus 21 bu/ac (2,016 kg/ha versus 1,176 kg/ha) in the control. The fact that there was fairly limited residual N carryover from Year 1 at the 6,000 and 9,000 gpa (67,800 and 101,700 L/ha) rates are revealed in the 20 bu/ac canola (1,120 kg/ha) yields that were little different than the control. The other contributing factor to low grain yields in these treatments was sulfur deficiency. Severe symptoms of nitrogen induced sulfur deficiency were observed in the filed in the urea (N only plots) and in the 6,000 and 9,000 gpa (67,800 and 101,700 L/ha) year 2000 single application plots (**Figure 11**). Further evidence is provided in high straw yield relative to grain yield in these single higher rate treatments. The urea provided the worst yield with only 11 bu/ac (616 kg/ha), but the highest straw yield. The sulfur deficiency seems to be more of an issue in manure fields the year after application, rather than the year of application. This is probably because there is more N relative to S than what the crop can use the first year, but the second year, the sulfur is gone and there is still residual N. Straw S concentrations were reduced by manure application, and were the lowest in the urea treatments (**Appendix III**).

Figure 11. Nitrogen Induced Sulfur Deficiency in Canola.

Fall available soil N levels in Fall 2001 after harvest were low and similar among treatments with around 36 lb/ac (40 kg/ha) of ammonium + nitrate 0 to 24 in (0 to 60 cm), except urea with slightly elevated surface nitrate content. Canola is a high N user.

4.1.3 2002 Results

In 2002, these plots had overlay treatments of:

- Control (no supplemental S fertilizer),
- 40 kg S / ha spring broadcast and incorporated elemental S,
- 40 kg S / ha spring broadcast and incorporated potassium sulfate.

This was in response to the observed S deficiency in canola grown on the urea and year 2 swine manure plots in 2001. The additional costs for the supplemental S fertilizer plots were funded by the Canadian Fertilizer Institute.

Available Nutrients: The amounts of available N in the soil profile in the spring of 2002 were elevated in the treatment plots that received manure in the fall of 2001, but the increase was only significant in the 6000 gpa rate. Most of the increase was confined to the top 30 cm of the soil profile and the available N levels (nitrate plus ammonium) in all treatments were less than 125 kg N/ha 0-60 cm, so there is no apparent large build-up of available N as nitrate in any of the treatments. Soil sulfate levels were lower than the control in the single large (9000 gpa) application made in 2000 and no applications made the following year. Soil sulfate levels in other treatments were not significantly affected by manure application. Consequently, application of manure tends to widen the N:S ratio to the point where a response to supplemental S fertilizer may be

anticipated. No significant effect of treatment was observed on soil extractable P, consistent with observations in the previous years and with the relatively low P content of the added manure. The surface soil pH and salinity were not significantly affected by the manure application. In the fall after harvest, the low and medium rates of swine manure increased residual inorganic N in the soil profile. The amounts of residual inorganic N ion general were less than 100 kg / ha in the 0-60cm depth.

Yield and Crop Composition: As in previous years, there was a significant yield response of the oats to manure injected the previous fall, with ~ 1500 kg / ha oat grain yield in the control to ~ 3000 kg/ha yield in the manure and urea fertilizer treatments. There was no significant difference between the 3000 gpa and the 6000 gpa treatments in terms of grain yield. The manure treatments yielded slightly but significantly higher than the urea treatment. It was noted in 2001, that the carryover from a single larger application in enhancing yield the second year was relatively low. This was observed again in 2002, with the single application made at 9000 gpa in the fall of 1999 having a similar yield to the unfertilized control. It would appear that smaller annual applications of manure in the range of 3000 gallons per acre(~ 100 kg N /ha) are more efficient than larger annual applications. The addition of supplemental fertilizer sulfur at 40 kg S / ha produced a significant yield response on the manured and urea N fertilized treatments. There was almost a doubling of oat yield from addition of sulfate as potassium sulfate and an intermediate effect from the elemental form of S. The addition of the S fertilizer had no significant effect on the S concentration in the grain, but addition of the S fertilizer significantly increased the plant S uptake in the manured or urea fertilized treatments. The sulfate form, being immediately available for plant use, produced the highest plant S uptake.

4.2 Loon Lake Result Analysis as Provided by Dr. Schoenau

4.2.1. 2000 Results

Manure analysis from the fall of 1999 treatments (**Appendix I**) indicated manure N application rates of 97 lb N/ac (109 kg N/ha) at 3,000 gpa (33,900 L/ha), 194 lb N/ac (217 kg N/ha) at 6,000 gpa (67,800 L/ha), and 291 lb N/ac (326 k N/ha) at 9,000 gpa (101,700 L/ha).

Application of hog manure significantly increased soil available nitrate in the 0 to 12 in (0 to 30 cm) depth only. There was no evidence of over winter leaching; however, it was dry at this site. In contrast, urea did not significantly affect spring available N. The urea N may have been temporarily immobilized by soil microbial population. Note that at this site, due to relatively high manure N content, the manure N application, even at the low

rate, was higher than the urea. There was no significant effect of manure on soil available P or K at this site.

Canola responded well to hog manure application with yields increasing from 20.7 bu/ac (1,160 kg/ha) in the check to 42.9 bu/ac (2,400 kg/ha) at 6,000 gpa (67,800 L/ha) to 57.0 bu/ac (3,193 kg/ha) at 9,000 gpa (101,700 L/ha). Barley was also responsive to manure application, from 20.5 bu/ac (1,100 kg/ha) in the check to 89.3 bu/ac (4,800 kg/ha). Yield with barley was maximized at the 6,000 gpa (67,800 L/ha) application rate. In contrast, pea yield did not significantly increase with the application of swine manure. This result was expected since pea will fix its own nitrogen in the absence of sufficient soil available N.

Fall of 2000, nitrate 0 to 24 in (0 to 60 cm) was low in the check plots and slightly higher in the pea stubble. In manured and urea plots, fall residual nitrate was higher than the control, especially in the pea plots. In general, there was a lot of ammonium in the Loon Lake soil, which tend to mask treatment effects. Available N (ammonium and nitrate) was about the same between manure treatments and controls (**Appendix IV**).

4.2.2 2001 Results (Swine Manure on Pea, Barley, and Flax)

Spring Available Nutrients: As expected, available N in the soil profile 0 to 24 in (0 to 60 cm) followed the pattern of manure addition increasing the profile inorganic N in both the low rate 2000 and 2001 applications and the single higher rates in 2000 only. Sulfate levels were not significantly affected by manure additions in the 0 to 12 in (0 to 30 cm) depth, suggesting some leaching of manure sulfate below the top foot. At this site, manure addition at the high rate in the first year did produce significantly higher levels of extractable P in the soil. There was a trend for extractable K to increase, but the increases were not statistically significant. The soil pH and electrical conductivity were not significantly affected by manure application with pH values near neutrality and E.C. values indicated non-saline conditions (**Appendix V**).

Pea: Pea showed a small and non-significant response to the second year of swine manure addition at the low rate 3,000 gpa (33,900 L/ha). A residual effect of the first year (2000) applications at 6,000 and 9,000 gpa (67,800 and 101,700 L/ha) into this year (2001) was also not apparent in pea yield. This is consistent with the 2000 results where pea response to injected manure was limited, owing to the ability of pea to fix nitrogen when soil available N levels are low. A big difference at this site in 2001 versus 2000 is the much lower pea yields in 2001 because of drought. Manure application did increase the total N uptake by the pea, as did the urea application. The sulfur concentration in grain was also increased by manure and urea.

Barley: Barley responded significantly in grain yields to the second (2001) application of swine manure at the low 3,000 gpa (33,900 L/ha) rate compared to the control, with a yield increase of about 20.5 bu/ac (1,100 kg/ha). The residual effect of the year one (2000) applications at the higher rates 6,000 and 9,000 gpa (67,800 and 101,700 L/ha) was also evident this year, with similar yield as the low rate 3,000 gpa (33,900 L/ha) for two successive years. Protein was also significantly increased from ~10% to 12.5% (still probably okay for malt). Grain S in barley also increased with manure.

Flax: Flax yields were low and were increased by manure and urea application, but only straw yields were significantly increased. Flax grain yield was not very responsive to nitrogen overall, which in consistent with our observation in the fertilizer nitrogen rate, form placement (greenhouse gas) field trails. Flax grain protein and sulfur concentration were also increased by manure.

4.2.3 Fall Available Soil N 2001

Soil levels of available N (ammonium + nitrate) in the soil profile determined after harvest revealed that manure application at the low rate for two years and the medium and high rate once at the beginning, resulted in slightly higher residual soil available N. There might have been a problem with the sampling of plots i.e. mix up between 2-0-0 and 3-0-0, which should be checked with the Agriculture and Agri-Food Canada (AAFC) field sampling crew. Still, there is not an alarming accumulation of inorganic N. Very little residual N is present as nitrate, much of it comes from ammonium in the 0 to 12 in (0 to 30 cm) layer (**Appendix VI**).

4.2.4 2002 Results

Severe drought condition in fall 2001 and throughout the growing season in 2002 resulted in complete crop failure with all crops.

5. Conclusions

Annual applications of swine manure at rates of approximately 3000 gallons per acre (approximately 100 kg N/ha) produced good yield responses on these Dark Gray Luvisolic soils, with no evidence of nutrient loading or deep migration by leaching. Larger single applications intended to last two or three years appear to be less effective on these soils, with less residual effect possibly due to immobilization of N in the soil organic matter or some unaccounted for N loss. To achieve optimum production on soils such as these, the application of supplemental sulphur fertilizer would be recommended to account for the low amount of sulphur added relative to nitrogen in the swine manure.

6. Personnel

PAMI Manpower Supplied

It is PAMI's policy to charge rates that include salary and benefits of employees as well as overhead. These charge rates do not include profits and to ensure that overhead is not charged to the project, indirect support services, management time, and use of PAMI equipment are provided at no cost. It has been calculated that this adjustment removes more than overhead costs from actual charge rates. It is PAMI's policy not to release individual salary information.

7. Equipment

A Case tractor was rented for this project in the fall of 1999. The PAMI manure injection truck was used in the fall of 2000 and in the fall of 2001.

8. Innovation Fund Acknowledgement

To date, the funding has been acknowledged at the Loon Lake site tour in summer of 2000. Project signage was installed in summer of 2000.

9. Project Public Information Materials

A Research Update outlining the results of the project will be written and distributed to PAMI subscribers. In addition and press release will publicize the Research Update. The Update will also be down loadable from the PAMI website.

Appendix I

2000 Manure Analysis

Concentrations in *Hog Manure* Applied at Melfort Crop Site in Fall 1999 for 2000 Season

	Tot. N	NH4	NO3	Tot. P	Avail P	K	Ca	Mg	Cu	Fe	Mn	Zn	B	Na
	ug/ml													
	1770	1590	-	38.5	1.40	1212	613	117	0.20	13	1.24	1.70	5.2	341
	Application rates of nutrient in kg/ha													
Rate gpa														
3330	65	59	-	1.4	0.05	45	23	4.3	0.01	0.5	0.05	0.06	0.2	12.7

Concentrations in *Hog Manure* Applied at Loon Lake Crop Site in Fall 1999 for 2000 Season

	Tot. N	NH4	NO3	Tot. P	Avail P	K	Ca	Mg	Cu	Fe	Mn	Zn	B	Na
	ug/ml													
	2618	1818	-	604	272	1047	504	293	1.40	51	7.9	12.7	8.3	301
	Application rates of nutrient in kg/ha													
Rate gpa														
3330	97	67	-	22	10.0	39	19	11	0.05	1.9	0.3	0.5	0.3	11.1

Appendix II

Melfort 2000 Results

2000: Dr. Jeff Schoenau's Crop Injected Hog Manure Experiment at Melfort

Coordinated by Dr. S.P. Mooleki — **2000 Wheat crop, and Spring & Fall Soil Samples**

2000 data revised.

December 21, 2001

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Melfort Crop and Spring Soil Results

Treatment	Trt	N	GrYldc*	GrYld	StYld	ToYld	GrNYld	GrProt	NO1	NO2	NO3	NH1	NH2	NH3	Av.N	Av.N	Av.N	Av.P	Av.K
Check	1	4	1143 d	1063 b	2283 b	3345 b	46.6	15.0 b	18.5 c	1.4 b	19.9 c	14.4 b	16.7	31.1	32.9 c	18.1	51.0 c	14.5	917
3000 gpa	2	4	1944 c	2083 a	3880 a	5963 a	58.8	15.0 b	44.2 b	5.3 a	49.5 b	18.0 b	18.1	36.1	62.2 bc	23.4	85.6 bc	13.8	859
6000 gpa	3	4	2400 b	2280 a	4113 a	6393 a	66.0	15.3 b	62.5 b	4.1 ab	66.6 b	24.5 b	18.1	42.5	87.0 b	22.2	109.2 b	14.6	905
9000 gpa	4	4	2673 a	2295 a	4030 a	6325 a	55.8	16.3 a	87.1 a	6.8 a	93.9 a	49.0 a	18.6	67.6	136.1 a	25.4	161.5 a	15.8	844
Urea	5	4	2654 a	2428 a	4163 a	6590 a	64.4	16.3 a	15.1 c	0.6 b	15.7 c	16.5 b	20.1	36.6	31.6 c	20.7	52.3 c	13.2	895
SE			77.5	334.4	409.9	728.9	12.4	0.4	11.1	1.8	11.9	11.1	5.0	13.6	15.9	5.6	18.2	3.3	74
$LSD_{(0.05)}$			169	729	893	1588	27.0	0.9	24.2	3.9	26.0	24.3	10.9	29.6	34.6	12.3	39.8	7.1	160
CV			5.1	23.3	15.7	18.0	30.1	3.7	34.6	68.9	34.4	64.4	38.5	44.9	32.1	36.3	28.1	32.2	11.8
MSE			12018	223593	336007	1062528	307.80	0.32	247.3	6.3	284.90	248.300	49.73	368.3	503.300	63.3	666.1	21.49	10826.00
Gr.Mean			2163	2030	3694	5723	58.3074	15.5536	45.4820	3.6464	49.1284	24.4798	18.2960	42.7754	69.9600	21.9422	91.9060	14.3934	883.9540

* GrYldc denotes Grain yield (kg/ha) obtained by combine harvesting treatment plots.
GrYld, StYld and ToYld are Grain yield, Straw yield and Total yield (kg/ha) based on square meter sampling.

Melfort fall soil results

Treatment	Trt	N	NO1	NO2	NO3	NH1	NH2	NH3	Av.N1	Av.N2	Av.N3
Check	1	4	15.2	3.3	18.5	11.9	11.7	23.6	27.0	15.1	42.1
3000 gpa	2	4	21.9	2.3	24.2	13.4	15.5	28.9	35.3	17.9	53.1
6000 gpa	3	4	31.1	5.0	36.1	10.6	11.2	21.9	41.8	16.2	57.9
9000 gpa	4	4	30.0	4.4	34.4	12.6	17.1	29.6	42.6	21.4	64.0
Urea	5	4	19.2	3.9	23.1	12.8	12.3	25.1	32.0	16.3	48.3
SE			8.1	1.3	8.6	3.1	2.8	5.5	8.4	3.2	9.5
$LSD_{(0.05)}$			17.7	2.8	18.6	6.7	6.0	12.1	18.3	7.0	20.6
CV			49.1	48.1	44.4	35.6	28.7	30.4	33.2	26.2	25.2
MSE			132.70	3.1040	146.30	19.0400	19.18	61.54	140.4	20.6	179.30
Gr.Mean			23.470	3.781	27.253	12.260	11.5712	25.8310	35.7302	17.3524	53.0824

Key: NO = NO_3 NH = NH_4 Av.N = Available N (i.e. NO_3 + NH_4) Av.P & K = Kelowna extractable P & K

Suffix **1, 2 & 3** denote soil depths 0-30, 30-60 & 0-60 cm, respectively. $T_{(0.05;\,12df)} = 2.179$

Appendix III

Melfort 2001 Results

2001: Dr. Jeff Schoenau's Crop Injected Hog Manure Experiment at Melfort

Coordinated by Dr. S.P. Mooleki — 2001 Canola crop, and Spring & Fall Soil Samples

December 21, 2001

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Melfort Canola Crop and Spring Soil Results

Trt	Rate		N	GrYldc*	GrYld	StYld	ToYld	GrNYld	StNYld	ToNYld	GrNConc	StNConc	ToNConc	GrProt	GrSConc	StSConc	ToSConc	NO1	NO2	NO3
1	0	0	4	1516	1155 b	3225 b	4380 c	34.3	11.9 c	46.1 b	29.7 c	3.7 b	33.4 c	15.7 c	3.14	4.05	7.19	11.7 b	1.3	13.0 b
2	1	1	4	1683	1975 a	4355 a	6330 a	68.2	24.8 bc	92.9 a	34.4 b	5.7 b	40.1 b	18.2 b	3.52	2.77	6.29	66.8 a	7.9	74.7 a
3	2	0	4	1331	1190 b	3850 ab	5040 bc	37.6	16.5 bc	54.0 b	32.5 bc	4.3 b	36.8 bc	17.2 bc	2.95	2.69	5.64	25.0 b	5.0	29.9 b
4	3	0	4	665	918 bc	4720 a	5638 a	31.2	29.0 b	60.2 b	36.4 b	6.0 b	42.4 b	19.3 b	3.05	2.51	5.56	24.0 b	7.0	31.0 b
5	U	U	4	1090	583 c	4897 a	5480 abc	24.7	57.0 a	81.7 a	41.6 a	11.9 a	53.5 a	22.0 a	3.78	1.88	5.66	22.4 b	4.2	26.5 b
		SE		505.4	257.2	435.3	525.5	9.1	6.9	7.6	2.2	1.2	2.8	1.1	0.34	0.68	0.92	7.2	2.4	8.9
		$LSD_{(0.05)}$		1101	560	949	1145	19.8	15.0	16.5	4.7	2.7	6.0	2.5	0.74	1.48	2.00	15.6	5.3	19.4
		CV		56.9	31.3	14.6	13.8	32.7	35.0	16.0	8.7	27.4	9.5	8.7	14.6	34.6	21.4	33.9	67.8	35.9
		MSE		510863	132315	379022	552395	164.40	94.32	114.7	9.3	3.00	15.290	2.62	0.2	0.924	1.7	102.9	11.80	158.30
		Gr.Mean		1257	1164	4208	5374	39.1822	27.8076	66.9900	34.9100	6.3238	41.2336	18.5022	3.2855	2.7791	6.0646	29.9554	5.0661	35.0212

N and S conc ($\mu g\ g^{-1}$)

* GrYldc denotes Grain yield (kg/ha) obtained by combine harvesting treatment plots.
GrYld, StYld and ToYld are Grain yield, Straw yield and Total yield (kg/ha) based on square meter sampling.

Melfort Crop and Spring Soil Results

Trt	Rate		N	NH1	NH2	NH3	Av.N	Av.N	Av.N	Av.S	Av.S	Av.S	Av.P	Av.K	pH1	pH2	pH3	EC1	EC2	EC3
1	0	0	4	20.2	20.3	40.5	31.9 b	21.6	53.5 b	120.7	128.2	248.9	18.0	1249.3 ab	7.42	7.70	7.56	0.130 b	0.142	0.136
2	1	1	4	20.3	20.2	40.5	87.1 a	28.1	115.2 a	171.0	135.4	306.3	14.7	1190.8 bc	7.66	7.52	7.59	0.205 a	0.097	0.151
3	2	0	4	20.0	20.0	39.9	44.9 b	25.0	69.9 b	156.4	127.1	283.5	15.0	1184.3 bc	7.54	7.79	7.67	0.133 b	0.132	0.132
4	3	0	4	17.2	17.4	34.6	41.1 b	24.4	65.6 b	142.8	124.1	266.9	14.3	1093.2 c	7.62	7.75	7.69	0.136 b	0.136	0.136
5	U	U	4	24.1	19.7	43.9	46.5 b	23.9	70.4 b	137.9	130.4	268.3	14.6	1350.8 a	7.38	7.51	7.44	0.124 b	0.100	0.112
		SE		2.4	2.6	4.1	7.4	3.6	9.2	31.2	29.7	35.5	3.2	56.5	0.10	0.28	0.18	0.014	0.033	0.019
		$LSD_{(0.05)}$		5.3	5.6	9.0	16.1	7.8	20.1	68.1	64.6	77.4	7.0	123.2	0.22	0.61	0.39	0.03	0.07	0.04
		CV		16.8	18.7	14.7	20.7	20.5	17.4	30.3	32.5	18.3	29.5	6.6	1.9	5.1	3.4	13.4	38.7	20.1
		MSE		12	13	34	109	25.47	170.00	1952.0	1759.0	2522.00	20.350	6394.00	0.0	0.154	0.1	0.0	0.00	0.00
		Gr.Mean		20	20	40	50	24.5964	74.9160	145.7540	129.0060	274.7580	15.3174	1213.6800	7.5250	7.6530	7.5890	0.1455	0.1212	0.1333

Melfort Fall Soil Results

Trt	Rate		N	NO1	NO2	NO3	NH1	NH2	NH3	Av.N1	Av.N2	Av.N3
1	0	0	4	4.0 b	1.0 b	5.1 b	18.0	17.8	35.7	22.0	18.8	40.8
2	1	1	4	6.0 b	1.1 b	7.1 b	17.0	15.1	32.1	23.0	16.2	39.2
3	2	0	4	4.8 b	1.4 b	6.2 b	16.6	16.7	33.3	21.4	18.1	39.5
4	3	0	4	4.8 b	1.0 b	5.9 b	14.9	15.3	30.2	19.7	16.4	36.1
5	U	U	4	29.2 a	3.7 a	32.9 a	17.8	16.4	34.2	47.0	20.1	67.2
		SE		8.4	0.6	8.9	2.8	2.4	4.8	9.5	2.3	10.4
		$LSD_{(0.05)}$		18.4	1.3	19.5	6.1	5.2	10.5	20.7	5.0	22.7
		CV		121.9	51.3	110.7	23.4	20.8	20.5	50.5	18.2	33.0
		MSE		141.900	0.726	160.200	13.540	11.460	46.240	180.700	10.640	216.400
		Gr.Mean		9.771	1.662	11.433	16.851	16.368	33.119	26.622	17.930	44.553

Suffix 1, 2 & 3 denote soil depths 0-30, 30-60 & 0-60 cm, respectively.
NO = NO_3 NH = NH_4 Av.N = Available N (i.e. NO_3 + NH_4)
Av.P & K = Kelowna extractable P & K

$T_{(0.05;\ 12df)} = 2.179$

Trt	Rate		2000	2001
1	0	0	Check	Check
2	1	1	3000gpa	3000gpa
3	2	0	6000gpa	0 gpa
4	3	0	9000gpa	0 gpa
5	U	U	Urea	Urea

Appendix IV

Loon Lake 2000 Results

2000: Dr. Jeff Schoenau's Crop Injected Hog Manure Experiment at Loon Lake

Coordinated by Dr. S.P. Mooleki — **2000 Spring Soil Samples** — ***December 21, 2000***

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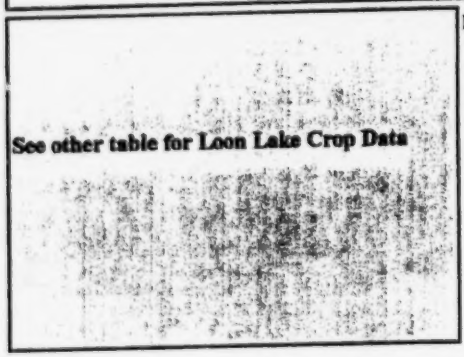
Loon Lake spring soil results

Treatment	Trt	N	NO1	NO2	NO3	NH1	NH2	NH3	Av.N1	Av.N2	Av.N3	Av.P1	Av.K1
Check	1	4	7.1 c	2.5	9.5	12.2	18.2	30.4	19.2 b	20.7	39.9	14.0	361
3000 gpa	2	4	23.1 b	5.5	28.6	13.3	16.5	29.8	36.4 ab	22.1	58.4	19.9	396
6000 gpa	3	4	12.8 bc	2.0	14.7	14.1	18.1	32.2	26.8 b	20.1	46.9	16.4	425
9000 gpa	4	4	29.3 a	6.5	35.9	19.4	18.5	37.9	48.8 a	25.0	73.8	19.6	446
Urea	5	4	8.3 bc	1.7	10.0	13.8	18.3	32.1	22.1 b	20.0	42.1	14.8	430
SE			6.9	3.3	9.6	2.9	2.2	4.9	8.1	4.8	12.2	4.6	26
$LSD_{(0.05)}$			**15.1**	**7.2**	**20.9**	**6.2**	**4.9**	**10.7**	**17.7**	**10.5**	**26.7**	**10.0**	**57**
CV			60.9	128.6	68.6	27.8	17.7	21.3	37.5	31.6	33.1	38.2	9.1
MSE			96.360	21.730	183.60	16.360	10.050	47.910	132.20	46.390	299.40	41.870	1391.0
Gr.Mean			16.1246	3.62474	19.7494	14.5454	17.937	32.4824	30.67	21.5618	52.232	16.9312	411.496



Key: NO = NO_3 NH = NH_4 Av.N = Available N (i.e. NO_3 + NH_4) Av.P & K = Kelowna extractable P & K

Suffix **1, 2 & 3** denote soil depths 0-30, 30-60 & 0-60 cm, respectively.

$T_{(0.05;\ 12df)}$ **= 2.179**

2000: Dr. Jeff Schoenau's Crop Injected Hog Manure Experiment at Loon Lake

Coordinated by Dr. S.P. Mooleki

REDONE >>

December 30, 2001

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Means

2000 CROP | **2000 FALL SOIL SAMPLES**

MTrt	Trt	N	GrYld	StYld	ToYld	NO1	NO2	NO3	NH1	NH2	NH3	Av.N1	Av.N2	Av.N3
Check	1	12	2939 d	4000 c	6939 d	4.3 c	1.1 b	5.4 c	8.6 a	12.7 a	21.3 a	12.9	13.8 a	26.7 ab
3000 gpa	2	12	4248 b	6631 ab	10879 b	7.4 bc	1.8 ab	9.2 bc	6.1 ab	8.6 b	14.6 b	13.5	10.4 b	23.8 b
6000 gpa	3	12	4545 b	6925 ab	11469 ab	13.1 a	2.9 a	15.9 a	5.8 ab	9.3 b	15.1 b	18.9	12.2 ab	31.1 a
9000 gpa	4	12	5064 a	7273 a	12337 a	12.2 ab	2.5 ab	14.7 ab	4.5 b	7.9 b	12.4 b	16.7	10.4 b	27.1 ab
Urea	5	12	3599 c	5737 b	9336 c	8.2 abc	2.2 ab	10.5 abc	7.2 ab	9.3 b	16.5 b	15.4	11.5 ab	26.9 ab
		SE	206	651	648	2.6	0.6	3.0	1.4	1.0	1.9	2.8	1.3	3.3
		$LSD_{(0.05)}$	449	1419	1411	5.6	1.2	6.5	3.0	2.3	4.2	6.1	2.8	7.2

Crop	Crop	N	GrYld	StYld	ToYld	NO1	NO2	NO3	NH1	NH2	NH3	Av.N1	Av.N2	Av.N3
Canola	1	20	2191 c	6393 b	8584 b	6.3 b	1.3 b	7.6 b	6.0	9.8	15.8	12.2 b	11.1	23.3 b
Pea	2	20	6597 a	7458 a	14054 a	12.7 a	2.9 a	15.7 a	6.8	9.7	16.5	19.6 a	12.6	32.2 a
Barley	3	20	3449 b	4489 c	7939 b	8.1 b	2.1 ab	10.2 b	6.5	9.2	15.7	14.6 b	11.3	25.9 b
		SE	151	426	496	1.7	0.4	2.0	1.1	0.7	1.5	2.3	0.9	2.9
		$LSD_{(0.05)}$	309	869	1013	3.5	0.9	4.2	2.1	1.4	3.1	4.7	1.8	6.0

Crop	MTrt	Trt	GrYld	StYld	ToYld	NO1	NO2	NO3	NH1	NH2	NH3	Av.N1	Av.N2	Av.N3
Canola	Check	1	1160 c	3221 c	4381 c	4.0	0.9	4.9	7.2	11.4	18.7	11.2	12.3	23.5
	3000 gpa	2	2216 b	6834 ab	9049 ab	6.1	1.0	7.1	5.4	9.9	15.3	11.6	10.9	22.4
	6000 gpa	3	2421 b	8706 a	11127 a	8.8	2.1	10.8	7.3	10.2	17.5	16.1	12.2	28.3
	9000 gpa	4	3193 a	6805 ab	9997 ab	6.9	1.1	7.9	4.5	9.0	13.6	11.4	10.1	21.5
	Urea	5	1967 b	6397 b	8363 b	5.7	1.4	7.1	5.3	8.5	13.8	11.0	9.9	20.9
Pea	Check	1	6472 a	7279	13751 ab	5.7 b	1.7 b	7.4 b	8.6	13.6 a	22.2 a	14.3	15.3	29.6
	3000 gpa	2	7090 a	7684	14774 a	11.1 ab	3.0 ab	14.1 ab	7.0	8.8 b	15.8 abc	18.1	11.8	29.9
	6000 gpa	3	6851 a	8120	14971 a	16.2 a	3.8 a	20.0 a	5.0	8.4 b	13.5 abc	21.3	12.2	33.5
	9000 gpa	4	7156 a	7785	14940 a	18.4 a	3.4 ab	21.8 a	4.3	7.4 b	11.7 c	22.8	10.7	33.5
	Urea	5	5414 b	6420	11834 b	12.1 ab	2.9 ab	15.0 ab	9.3	10.1 ab	19.3 ab	21.4	12.9	34.3
Barley	Check	1	1185 c	1500 d	2685 c	3.3 b	0.8 b	4.0 b	9.9 a	13.0 a	22.9 a	13.2	13.8 a	27.0
	3000 gpa	2	3439 b	5376 abc	8815 b	4.9 b	1.4 ab	6.3 b	5.8 ab	7.0 b	12.8 b	10.7	8.4 b	19.1
	6000 gpa	3	4363 a	3948 c	8310 b	14.2 a	2.8 ab	17.0 a	5.1 ab	9.3 b	14.4 b	19.3	12.1 ab	31.4
	9000 gpa	4	4845 a	7228 a	12073 a	11.3 ab	3.1 a	14.4 ab	4.5 b	7.3 b	11.9 b	15.8	10.4 ab	26.3
	Urea	5	3416 b	4395 bc	7811 b	6.9 ab	2.4 ab	9.3 ab	7.0 ab	9.3 b	16.3 ab	13.9	11.7 ab	25.6
		SE	345	1014	1113	4.0	1.0	4.8	2.4	1.6	3.4	5.1	2.0	6.3
		$LSD_{(0.05)}$	770	2292	2473	9.1	2.1	10.7	5.2	3.7	7.5	11.2	4.6	13.8
		CV	12	22	15	59.7	64.6	57.7	51.8	22.7	29.9	47.1	23.6	34.2
		MSEa	255316	2544903	2515689	39.44	1.92	55.46	11.34	6.47	22.31	47.53	9.70	65.37
		MSEb	229406	1811596	2461724	29.19	1.83	41.37	11.06	4.68	22.79	33.12	7.36	86.21
		Gr.Mean	4079	6113	10192	9.0	2.1	11.2	6.4	9.6	16.0	15.5	11.7	27.1
	Weighted t =		2.23	2.26	2.22	2.26	2.22	2.25	2.22	2.26	2.22	2.21	2.25	2.19

Appendix V

Loon Lake 2001 Results

2001: Dr. Jeff Schoenau's Crop Injected Hog Manure Experiment at Loon Lake

Coordinated by Dr. S.P. Mooleki — **2001 Spring Soil Samples**

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MEANS

Trt	Rate		N	NO1	NO2	NO3	NH1	NH2	NH3	Av.N1	Av.N2	Av.N3	SO1
1	0	0	4	33.1	5.8	39.0 b	13.6	15.5	29.1	46.7 b	21.4	68.1 b	48.6
2	1	1	4	41.3	6.8	48.1 b	11.9	13.5	25.4	53.2 b	20.3	73.5 b	33.1
3	2	0	4	53.4	7.4	60.8 ab	8.4	11.4	19.8	61.8 ab	18.8	80.6 b	49.1
4	3	0	4	68.4	13.8	82.2 a	15.1	12.4	27.4	83.5 a	26.2	109.7 a	61.8
5	u	u	4	50.6	15.3	65.9 ab	10.8	9.4	20.2	61.4 ab	24.7	86.0 ab	41.4
			SE	10.9	5.2	12.8	2.5	2.3	3.7	10.2	5.3	11.2	18.3
			$LSD_{(0.05)}$	**23.9**	**11.4**	**28.0**	**5.4**	**5.0**	**8.0**	**22.2**	**11.5**	**24.3**	**39.9**
			CV	31.4	75.3	30.7	29.5	26.0	21.2	23.5	33.6	18.9	55.3
			MSE	240	55	330	12	10.51	26.82	207.0	56.1	248.70	669.800
			Gr.Mean	49.4	9.8	59.2	11.9	12.5	24.4	61.3	22.3	83.6	46.8

Trt	Rate		N	SO2	SO3	Av.P1	Av.K1	pH1	pH2	pH3	EC1	EC2	EC3
1	0	0	4	17.7 c	66.3	21.3 b	511.5	7.5	7.5	7.5	0.1	0.1	0.1
2	1	1	4	33.6 abc	66.7	19.8 b	547.7	7.7	7.4	7.6	0.2	0.3	0.2
3	2	0	4	54.6 a	103.7	27.2 ab	582.6	7.6	7.4	7.5	0.2	0.1	0.1
4	3	0	4	46.6 ab	108.4	40.9 a	594.3	7.6	7.6	7.6	0.2	0.3	0.3
5	u	u	4	44.0 ab	85.3	14.5 b	562.4	7.5	7.5	7.5	0.1	0.1	0.1
			SE	9.8	17.3	7.7	54.1	0.2	0.1	0.1	0.0	0.2	0.1
			$LSD_{(0.05)}$	**21.3**	**37.7**	**16.7**	**117.8**	**0.4**	**0.2**	**0.3**	**0.1**	**0.4**	**0.2**
			CV	35.2	28.4	43.9	13.7	3.1	2.1	2.2	27.6	122.8	63.8
			MSE	192	598	118	5848	0.05	0.02	0.0	0.0	0.06	0.013
			Gr.Mean	39.3	86.1	24.7	559.7	7.6	7.5	7.5	0.2	0.2	0.2

NO = NO_3 NH = NH_4 Av.N = Available N (i.e. NO_3 + NH_4)

SO = SO_4 kg/ha (2 M KCl ectracted) $T_{(0.05;\ 12df)} = 2.179$

EC = Electrical conductivity (mS/cm)

Av.P and Av.K = Modified Kelowna extractable P and K, respectively (kg/ha)

Suffices 1, 2 & 3 denote soil depth 0-30, 30-60 & 0-60 cm, respectively.

Trt	Rate		2000	2001
1	0	0	Check	Check
2	1	1	3000gpa	3000gpa
3	2	0	6000gpa	0 gpa
4	3	0	9000gpa	0 gpa
5	U	U	Urea	Urea

2001: Dr. Jeff Schoenau's Hog Manure Experiment at Loon Lake

Coordinated by Dr. S.P. Mooleki — **2001 Pea, Barley & Flax crops, and Fall soil samples** — *December 23, 2001*

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Means

2001 Pea, Barley & Flax crops

Trt	Rate		N	GrYld	StYld	ToYld	GrNYld	StNYld	ToNYld	GrNConc	StNConc	ToNConc	GrProt	GrSConc	StSConc	ToSConc
1	0	0	12	1412 d	1884 b	3296 c	35.1 c	27.5 d	62.6 d	27.9 d	15.2 c	43.1 d	16.4 d	2.3 d	2.1	4.4
2	1	1	12	1930 a	2947 a	4877 a	51.5 a	49.1 ab	100.5 ab	31.1 b	17.0 b	48.1 b	18.2 b	2.4 c	2.5	4.9
3	2	0	12	1723 b	2197 b	3921 bc	43.0 b	33.5 cd	76.5 c	29.2 c	15.3 c	44.5 cd	17.1 c	2.4 c	2.7	5.0
4	3	0	12	1849 ab	2551 ab	4400 ab	49.2 a	41.1 bc	90.3 b	30.5 b	16.3 bc	46.8 bc	17.9 b	2.5 b	2.5	5.0
5	u	u	12	1786 a	2953 a	4739 a	50.5 a	56.0 a	106.4 a	33.3 a	19.5 a	52.8 a	19.4 a	2.6 a	2.3	4.9
		SE		50	308	327	1.6	4.3	4.8	0.6	0.8	1.2	0.3	0.0	0.2	0.2
		$LSD_{(0.05)}$		109	670	713	3.5	9.3	10.5	1.2	1.7	2.6	0.7	0.1	0.4	0.5

Crop	Crop	N	GrYld	StYld	ToYld	GrNYld	StNYld	ToNYld	GrNConc	StNConc	ToNConc	GrProt	GrSConc	StSConc	ToSConc
Pea	1	20	1559 b	2011 b	3571 b	53.2 a	39.3 b	92.5 a	34.1 b	19.6 a	53.7 b	21.3 a	2.5 b	3.0 a	5.4 a
Barley	2	20	2903 a	2627 a	5530 a	55.4 a	34.9 b	90.2 a	18.9 c	13.2 c	32.1 c	11.8 c	1.8 c	1.6 c	3.5 b
Flax	3	20	758 c	2881 a	3639 b	29.0 b	50.1 a	79.0 b	38.1 a	17.1 b	55.3 a	20.2 b	3.0 a	2.7 b	5.6 c
	SE		55	180	193	1.6	3.1	3.4	0.3	0.6	0.7	0.2	0.0	0.2	0.2
	$LSD_{(0.05)}$		112	368	394	3.2	6.4	6.9	0.6	1.3	1.5	0.4	0.1	0.4	0.4

Crop	Trt	Rate		N	GrYld	StYld	ToYld	GrNYld	StNYld	ToNYld	GrNConc	StNConc	ToNConc	GrProt	GrSConc	StSConc	ToSConc
Pea	1	0	0	4	1518 ab	1399 b	2917 b	51.6	26.7 a	78.3 c	34.1 b	19.2 b	53.3 b	21.3 ab	2.3 c	2.5	4.8 b
	2	1	1	4	1699 a	2358 ab	4057 a	56.8	44.6 ab	101.4 ab	33.4 b	19.1 b	52.6 b	20.9 b	2.4 bc	2.9	5.3 ab
	3	2	0	4	1520 ab	1885 ab	3406 ab	51.4	33.6 bc	85.1 bc	33.8 b	17.8 b	51.7 b	21.1 b	2.5 ab	3.2	5.7 a
	4	3	0	4	1607 ab	2046 ab	3653 ab	54.3	39.4 abc	93.6 abc	33.8 b	19.1 b	52.8 b	21.1 b	2.6 a	3.3	5.9 a
	5	u	u	4	1452 b	2369 a	3821 ab	51.8	52.4 a	104.2 a	35.7 a	22.7 a	58.4 a	22.3 a	2.5 ab	2.9	5.4 ab
Barley	1	0	0	4	2100 c	2175 b	4275 c	32.7 c	24.8 b	57.5 c	15.6 a	11.5 b	27.1 d	9.8 c	1.6 d	1.6	3.3
	2	1	1	4	3264 a	2895 ab	6159 ab	65.2 a	37.6 ab	102.8 a	20.2 a	13.6 ab	33.8 ab	12.6 a	1.8 bc	1.7	3.5
	3	2	0	4	2938 b	2182 ab	5120 bc	52.1 b	26.4 b	78.5 b	17.8 b	11.9 b	29.7 cd	11.1 b	1.7 cd	1.5	3.2
	4	3	0	4	3110 ab	2677 ab	5787 ab	62.0 b	35.4 ab	97.4 a	20.0 a	13.2 ab	33.2 bc	12.5 a	1.8 bc	1.6	3.4
	5	u	u	4	3102 ab	3207 a	6309 a	64.8 b	50.0 a	114.8 a	20.9 a	15.9 a	36.8 a	13.1 a	2.1 a	1.8	4.0
Flax	1	0	0	4	616	2078 b	2695 b	20.9 c	31.0 c	51.9 d	34.0 e	14.9 c	48.9 d	18.0 a	2.8 c	2.3 b	5.1 b
	2	1	1	4	826	3589 a	4415 a	32.4 ab	64.9 a	97.3 ab	39.7 b	18.2 ab	57.9 b	21.1 b	3.0 ab	3.0 ab	6.0 a
	3	2	0	4	712	2525 ab	3237 ab	25.5 bc	40.4 bc	65.9 cd	36.0 d	16.1 bc	52.1 cd	19.1 d	2.9 bc	3.3 a	6.1 a
	4	3	0	4	830	2931 ab	3762 ab	31.3 ab	48.6 b	79.9 bc	37.7 c	16.5 bc	54.2 bc	20.0 c	3.1 a	2.5 ab	5.6 ab
	5	u	u	4	804	3284 a	4088 a	34.7 a	65.5 a	100.2 a	43.2 a	20.0 a	63.2 a	22.9 a	3.0 ab	2.3 b	5.3 ab
			SE		112	450	481	3.3	7.2	7.8	0.8	1.4	1.8	0.5	0.1	0.4	0.4
			$LSD_{(0.05)}$		241	1031	1099	7.1	16.0	17.5	1.8	3.1	4.0	1.1	0.2	0.9	0.9
			CV		10	23	14	10.8	24.0	12.2	3.2	11.9	5.0	3.1	4.5	24.4	12.5
			MSEa		15079	567533	642793	15.07	109.69	138.20	1.89	3.76	8.24	0.66	0.01	0.24	0.28
			MSEb		10272	324799	371626	24.56	98.99	114.00	0.92	3.92	5.42	0.31	0.01	0.35	0.37
			Gr.Mean		1740	2507	4246	45.8	41.4	87.3	30.4	16.6	47.0	17.8	2.4	2.4	4.8
			Weighted t =		2.15	2.29	2.29	2.17	2.23	2.24	2.31	2.21	2.27	2.31	2.18	2.18	2.19

Appendix VI

Loon Lake 2001 Fall Results

2001: Dr. Jeff Schoenau's Hog Manure Experiment at Loon Lake

Coordinated by Dr. S.P. Mooleki — **2001 Pea, Barley & Flax crops, and Fall soil samples**

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Means

Fall soil samples

Trt	Rate		N	NO1	NO2	NO3	NH1	NH2	NH3	Av.N1	Av.N2	Av.N3
1	0	0	12	8.8 c	2.8	11.6 b	13.5 b	15.8	29.3 b	22.3 b	18.6	40.9 b
2	1	1	12	14.3 ab	2.1	16.5 ab	19.5 b	17.0	36.5 b	33.8 b	19.1	53.0 b
3	2	0	12	9.6 bc	2.0	11.6 b	92.3 a	20.6	112.9 a	101.8 a	22.7	124.5 a
4	3	0	12	17.0 a	3.2	20.2 a	13.2 b	15.2	28.4 b	30.2 b	18.5	48.7 b
5	U	U	12	17.7 a	3.6	21.3 a	13.0 b	15.8	28.8 b	30.7 b	19.3	50.0 b
			SE	2.4	1.1	2.9	20.2	2.2	21.3	20.4	2.7	21.9
			$LSD_{(0.05)}$	5.1	2.3	6.4	44.0	4.8	46.5	44.4	5.9	47.8

Crop	Crop	N	NO1	NO2	NO3	NH1	NH2	NH3	Av.N1	Av.N2	Av.N3
Pea	1	20	20.9 a	4.3 a	25.2 a	30.0	15.9	45.9	50.9	20.2	71.1
Barley	2	20	13.7 b	2.0 b	15.7 b	29.4	17.0	46.5	43.1	19.1	62.2
Flax	3	20	5.8 c	2.0 b	7.8 c	31.5	17.7	49.2	37.3	19.7	57.0
		SE	2.2	0.7	2.5	13.3	1.3	14.3	13.3	1.5	14.3
		$LSD_{(0.05)}$	4.4	1.4	5.2	27.1	2.6	29.2	27.2	3.0	29.2

Crop	Trt	Rate		N	NO1	NO2	NO3	NH1	NH2	NH3	Av.N1	Av.N2	Av.N3
Pea	1	0	0	4	12.6 b	6.3	18.9 bc	15.6	16.4	32.0	28.3	22.7	50.9
	2	1	1	4	28.4 a	3.2	31.5 a	34.7	16.1	50.8	63.0	19.3	82.3
	3	2	0	4	14.7 b	3.6	18.3 c	74.3	18.2	92.5	89.0	21.9	110.9
	4	3	0	4	26.5 a	4.0	30.5 ab	12.3	13.9	26.2	38.8	17.9	56.7
	5	U	U	4	22.5 ab	4.3	26.8 abc	13.0	14.9	27.9	35.4	19.2	54.6
Barley	1	0	0	4	11.1	1.4	12.4	12.5 b	15.5	28.0 b	23.5 b	16.9	40.5 b
	2	1	1	4	11.5	2.0	13.6	12.0 b	18.9	30.9 b	23.5 b	20.9	44.4 b
	3	2	0	4	10.5	1.3	11.8	98.1 a	18.9	117.0 a	108.7 a	20.2	128.8 a
	4	3	0	4	16.4	2.6	18.9	11.9 b	16.1	28.0 b	28.3 b	18.7	47.0 b
	5	U	U	4	19.0	2.8	21.8	12.6 b	15.8	28.4 b	31.6 b	18.6	50.1 b
Flax	1	0	0	4	2.7	0.8	3.5	12.4 b	15.4 b	27.8 b	15.1 b	16.2 b	31.4 b
	2	1	1	4	3.1	1.2	4.3	11.9 b	15.9 b	27.8 b	15.0 b	17.2 b	32.1 b
	3	2	0	4	3.5	1.2	4.7	104.4 a	24.8 a	129.2 a	107.8 a	26.0 a	133.8 a
	4	3	0	4	8.1	3.2	11.3	15.5 b	15.6 b	31.1 b	23.6 b	18.8 ab	42.4 b
	5	U	U	4	11.7	3.6	15.3	13.4 b	16.6 b	30.0 b	25.1 b	20.2 ab	45.3 b
			SE		4.6	1.7	5.5	31.5	3.2	33.7	31.7	3.8	34.1
			$LSD_{(0.05)}$		10.0	3.8	12.1	71.2	7.4	76.8	71.7	8.8	77.1
			CV		50.8	80.8	49.6	138.5	24.0	96.0	96.1	23.6	71.4
			MSEa		33.24	6.73	51.79	3448.0	29.63	2728.0	2492.0	46.23	2888.0
			MSEb		46.84	4.99	64.83	1760.0	10.36	2051.0	1770.0	21.53	2049.0
			Gr.Mean		13.5	2.8	16.2	30.3	16.9	47.2	43.8	19.6	63.4
			Weighted t =		2.18	2.26	2.19	2.26	2.29	2.25	2.26	2.31	2.26

Suffix 1, 2 & 3 denote soil depths 0-30, 30-60 & 0-60 cm, respectively.

NO = NO_3 NH = NH_4

Av.N = Available N (i.e. NO_3 + NH_4)

Av.P & K = Kelowna extractable P & K

Trt	Rate		2000	2001
1	0	0	Check	Check
2	1	1	3000gpa	3000gpa
3	2	0	6000gpa	0 gpa
4	3	0	9000gpa	0 gpa
5	U	U	Urea	Urea

LSD calculation according to Gomez & Gomez (1984) pages 199 & 200.

Problems with AAFC sampling(?)

Appendix VII

Project Summary

Soil and Crop Response to Injected Liquid Swine Manure on Two Gray Luvisols

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Keywords: Swine manure, Gray soils and available N.

Introduction

Intensive livestock production is increasing in western Canada, and so is the need to dispose of the manure produced. In the last six years or so, the Saskatchewan Centre for Soil Research at the University of Saskatchewan in conjunction with researchers at Prairie Agricultural Machinery Institute (PAMI) and Agriculture and Agri-Food Canada (AAFC) have carried out studies in various areas of manure management. The overall aim of these studies is to determine the viability and sustainability of manure application to agricultural land. The impact of livestock manure application to land is influenced by various factors, among them: soil characteristics, climatic conditions, cropping systems, manure handling and application techniques. Thus, manure management is bound to be site-specific. In order to come up with viable site-specific manure management recommendations, studies have to be conducted in various regions representing the diverse agricultural zones of the province. Although there are various aspects of the impact of manure application to agricultural land, both long-term and short-term, the immediate impact of manure application is typically exhibited in enhanced availability of N in the soil, crop yield and plant N concentration. This is more so with swine manure which has a relatively high concentration of inorganic N. Hence, the objective of this study was to determine the effects of rate and frequency of swine manure application on crop performance and soil available N in the Gray and Dark Gray Soil Zones of Saskatchewan.

Materials and methods

The experiment was initiated in 1999 at Melfort (SW26 Tp44 R18 W2) and Loon Lake (SW32 Tp58 R21 W3). Although soils around Melfort are typically described as Thick Black Chernozems, there are pockets under wooded areas falling into other descriptions. The Melfort site was located on a field with soil classified as Dark Gray Luvisol (Kamsack Association) of clay loam texture. The Loon Lake site was situated on a Gray Luvisol (Loon River Association) of loam texture. Liquid swine manure was injected into the soil using the PAMI manure tanker truck fitted with low disturbance coulter injection system in the fall prior to each cropping season. Four rates of manure application (none, low, medium and high) were used. The low rate was applied at 3000 gallons per acre. The medium and high rates were double and triple multiples of the low rate, respectively. The low rate was applied annually. The medium rate was applied in the first and the third year, while the high rate was applied only in the first year. A fifth treatment of urea at soil-test recommended rate was included and applied annually at the time of seeding. Thus, the five treatments were coded as **000**, **111**, **202**, **300** and **uuu**, respectively. At the time of manure application, manure samples were taken for the determination of nutrient content later in the

laboratory. Table 1 gives the actual rates of inorganic N (mainly ammonium-N) applied per year at each location in the three years of the study.

The treatments were arranged in a RCBD with four replications at each site. However, at Loon Lake, three crops were seeded across the main treatments each year, thus changing the experiment to a split-plot design. Hence, statistical analysis was conducted separately based on the two experimental designs. At Melfort, wheat, canola and oats were seeded in 2000, 2001 and 2002, respectively. At Loon Lake, canola, pea and barley were seeded in rotation during the three years of the study. Flax was seeded in place of canola in 2001. Soil samples were taken in the spring prior to seeding and in the fall after harvesting. The soil samples were analyzed for various variables including inorganic N. Crop samples were taken for the determination of grain yield and N concentration.

Table 1. Inorganic N concentration in the liquid swine manure applied at Melfort and Loon Lake for the growing seasons 2000, 2001 and 2002

	Manure application Rates		
Regime	2000	2001	2002
Melfort	----- (Av.N kg/ha) -----		
1	0	0	0
2	54	73	80
3	108	0	160
4	162	0	0
5	80	80	80
Loon Lake			
1	0	0	0
2	61	30	84
3	122	0	168
4	183	0	0
5	80	80	80

Results and discussion

Injection of liquid swine manure significantly increased pre-seeding available soil N at Melfort in 2000 (Fig. 1). At Loon Lake, pre-seeding available soil N was not significantly different from that in the control treatment except at the high rate of application. The urea treatment at both locations exhibited pre-seeding available soil N similar to those in the control plots because the urea was applied after sampling. The low enhancement of pre-seeding available soil N at Loon Lake may be due to immobilization of N in the manure. Similarly, in 2001, pre-seeding available soil N was significantly higher than the control at Melfort but not at Loon Lake. Treatments **202** and **300** at Loon Lake, exhibited higher pre-seeding available soil N although these treatments did not receive manure applications for that growing season. This could be attributed to the release of the N that was immobilized in the first year as well as carry-over of residual inorganic N. At Melfort, treatments **202** and **300** showed no significant difference in available soil N than that observed in the control, suggesting low residual effect of higher rates of manure application in these soils. In 2002, swine manure application enhanced pre-seeding available N in both the **111** and **202** treatments, but only the latter showed a significant enhancement in pre-seeding

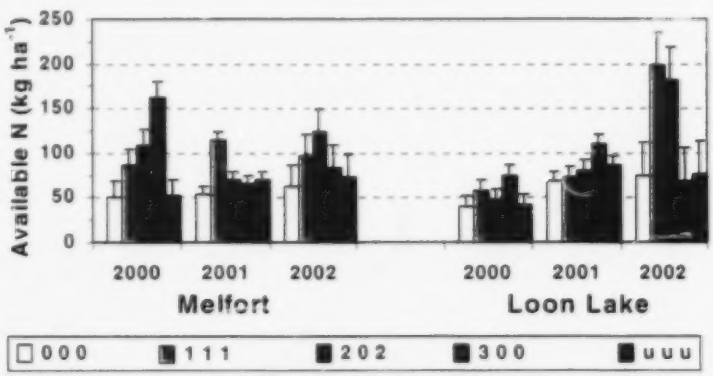

Fig. 1. Effect of liquid swine manure application rate and frequency on pre-seeding available soil N at Melfort and Loon Lake.

available soil N over the control. At Loon Lake, both treatments 111 and 202 significantly enhanced pre-seeding available soil N as compared to the control. No significant residual effect of high rate of swine manure application was observed at both locations by the third year following application.

At Melfort, post-harvest available soil N was generally low (Fig. 2). In 2000, only at the high application rate of swine manure was a significant elevation in post-harvest available soil N observed. In 2001, post-harvest available soil N in all manure treated plots was not different from that in the control. However, treatments treated with urea exhibited a significant post-harvest available soil N. This could be attributed to poor utilization of the urea by the canola crop, which showed significant effects of sulfur deficiency (Schoenau et al. 2003). In 2002, only treatment **202** exhibited a significant elevation in post-harvest available soil N compared to the control.

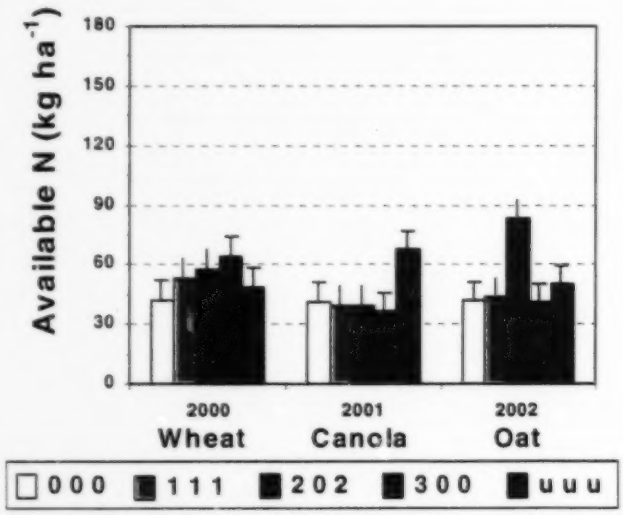

Fig. 2. Effect of liquid swine manure and urea application rate and frequency on post-harvest available soil N at Melfort.

At Loon Lake, no significant elevation in post-harvest available soil N was observed in all treatments in 2000 (Fig. 3). In 2001, significant elevation in post-harvest available soil N was observed, particularly in treatment **202**. It is not clear as to why treatment **202** exhibited significantly higher post-harvest available soil N than treatment 300, both of which received no manure application for the 2001 season, with the latter having received a higher rate of swine manure application. As no plausible explanation can be given for the elevated post-harvest available soil N in treatment **202**, it can generally be noted that manure and urea application did not significantly enhance post-harvest available soil N.

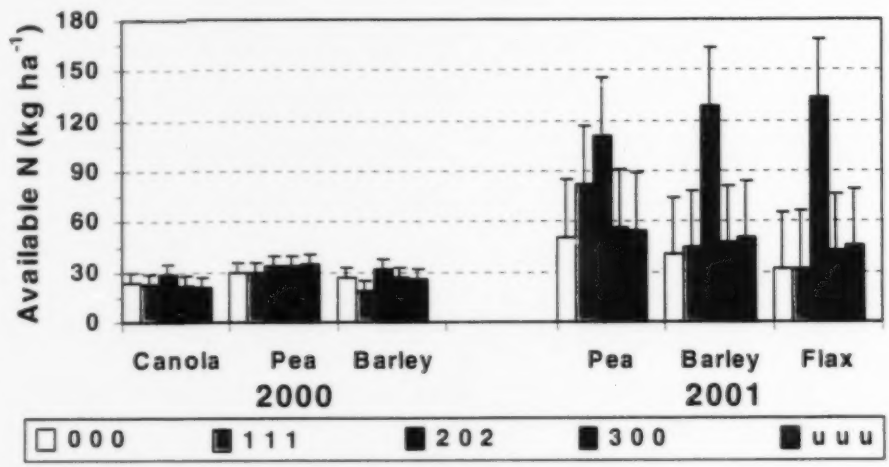

Fig. 3. Effect of liquid swine manure and urea application rate and frequency on post-harvest available soil N at Loon Lake in 2000 and 2001.

At Melfort, application of swine manure and urea significantly increased grain yield of wheat in 2000 (Fig. 4). No significant differences in wheat grain yields were observed in manure treated plots beyond that observed at the low rate of application. Wheat grain yields in manure treated

plots were comparable to those receiving urea. In 2001, swine manure application at the low rate produced significantly higher than that of any other treatment. Treatments **202** and **300**, which received no manure in 2001, resulted in low canola grain yields, comparable to the control plots. Urea application at 80 kg ha^{-1} resulted in the lowest canola grain yield. Plots receiving urea only exhibited severe symptoms of sulfur deficiency (Schoenau, et al. 2003). In 2002, grain yield of oats was significantly elevated by both swine manure and urea application. No significant response to rate was observed, probably due to the dry conditions. However, since similar lack of response to rate was observed in the first year with relatively sufficient moisture, the results suggest that applying manure at rates higher than 3000 gpa in these soils may result in no added grain yield benefit. The comparative increase in grain yield of oats in the urea treated plots also show that cereal crops are not as sensitive to the low S levels in these soils.

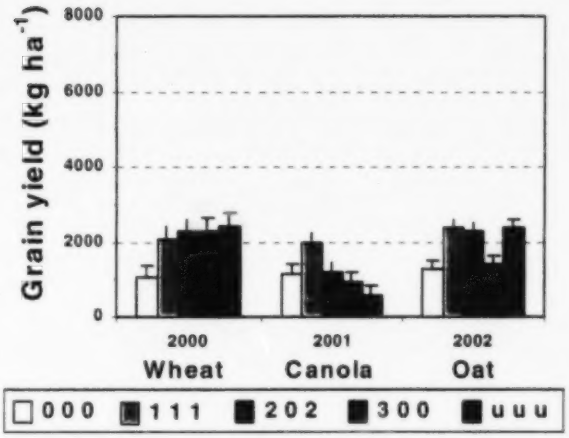

Fig. 4. Effect of liquid swine manure and urea application rate and frequency on grain yield of wheat, canola and oats in 2000, 2001 and 2002, respectively, at Melfort.

At Loon Lake, swine manure and urea application significantly increased canola and barley grain yield in 2000 (Fig. 5). A significant response to the rate of manure application was also observed in these crops. The effect of urea application on grain yield of canola and barley was comparable to that of the low rate of swine manure. Grain yield of pea was high and no difference was observed between manure treated plots and the control. However, pea grain yield was suppressed by urea application.

In 2001, no significant grain yield differences were observed in pea and flax crops. On the other hand, barley grain yields in the swine manure and urea treated plots were significantly higher than that in the control. The lack of response to the rate of manure application or urea application was attributed to the drought of that year. The pea and flax crops were more affected by the drought due to the openness of their canopies which under such situations render them poor competitors with weeds for scarce moisture, or lose more moisture through evaporation.

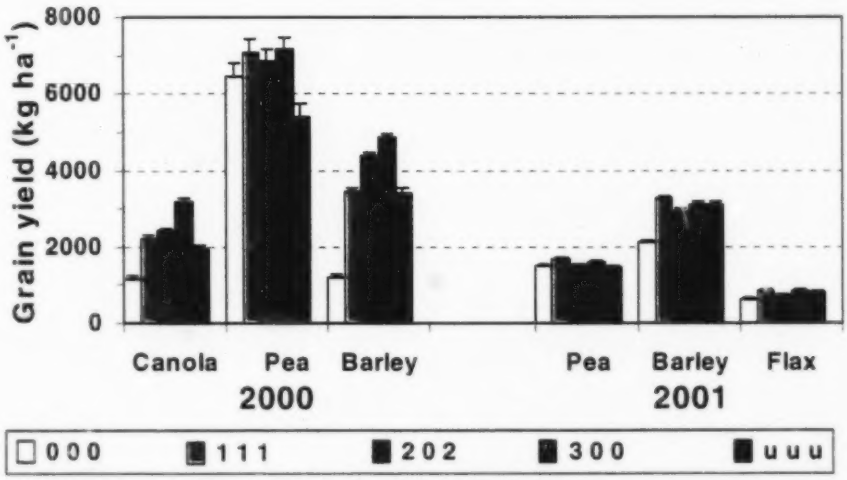

Fig. 5. Effect of liquid swine manure and urea application rate and frequency on grain yield of canola, pea and barley in 2000, and pea, barley and flax in 2001 at Loon Lake.

At Melfort in 2000, grain protein of wheat was significantly enhanced by swine manure application at the high rate and by urea application (Fig. 6). In 2001, canola grain protein concentration was highest in the urea treated plots, which also yielded the lowest. Treatments **111** and **300** also resulted in significantly higher protein concentration compared to the control. No difference in canola grain protein was observed between treatment **202** and the control. Grain protein concentration of oats seeded in 2002 showed less response to swine manure application. Only treatment **202** and **uuu** showed small but a significant increase in grain protein compared to the control.

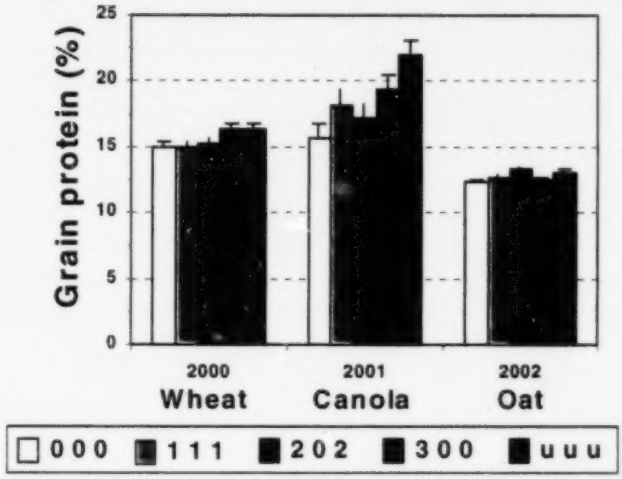

Fig. 6. Effect of liquid swine manure and urea application rate and frequency on grain protein of wheat, canola and oats in 2000, 2001 and 2002, respectively, at Melfort.

At Loon Lake in 2000, both canola and barley showed significant increase in grain protein concentration over the control, with the highest values observed at the high rate of swine manure (Fig. 7). In peas, no significant difference in grain protein was observed between manure treated plots and the control. However, urea treated plots exhibited higher pea grain protein concentration than high manure rate treated plots. In 2001 at Loon Lake, pea grain protein concentration in urea treated plots was higher than in any other treatment. Manure treated plots were not different from the control. A significant grain protein concentration response to rate of manure application was observed in barley and flax. In barley, no significant difference in grain protein concentration was observed among the **111**, **300** and **uuu** treatments. However, in both barley and flax, the **uuu** treatment resulted in the highest grain protein concentration.

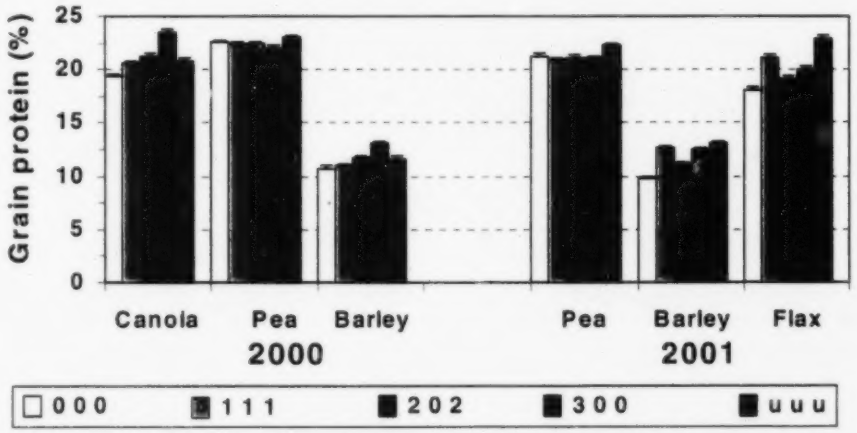

Fig. 7. Effect of liquid swine manure and urea application rate and frequency on grain protein of canola, pea and barley in 2000, and pea, barley and flax in 2001 at Loon Lake.

The elevation of pre-seeding available soil N following swine manure application have been observed in other soil zones (Pastl, et al. 2000; Mooleki, et al. 2002; Grevers, 2002;). Under ideal conditions, this results in enhanced crop yield in non-leguminous crops as observed at Melfort and Loon Lake in the first year. Grain protein concentration may also increase. The effect of swine manure application on available soil N and crop performance is comparable to that of chemical N fertilizer. This is attributed to the high (60 –

80%) inorganic N available in the manure or becoming available over the growing season (Qian and Schoenau, 2000). Like chemical N fertilizers, the advantages of manure application are suppressed under droughty situations as observed at both Melfort and Loon Lake in 2001 and 2002. Unlike chemical N fertilizers, swine manure supplies other nutrients, which may help offset nutrient deficiencies in sensitive crops – e.g. S deficiency in canola as observed in 2001 at Melfort (Fig. 4). These results also show that swine manure application in excess of 3000 gpa (approx. 80 kg N ha^{-1}) may not result in increased grain yield in the year of application. Unlike in the Black, Dark Brown and Brown soil zones (Mooleki, et al. 2002; Grevers, 2002) where the residual N from high rates of manure lasted at least two years, the residual effect of high rate of swine manure in the Gray soils seems to be shorter. This can also be seen from the low post-harvest available soil N. Given the more moist conditions of these environments, the low residual effect of high rates of swine manure application may be attributed to leaching or gaseous losses, or immobilization in the soil organic matter.

Conclusions

Liquid swine manure application in the Gray soils is a sustainable practice. The residual effect of high manure application and the low increase in grain yield above that obtained from the low rate of manure application indicate that annual application at low rates would be a better practice.

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References

Grevers, M. 2002. The long-term effect of repeated application of hog manure on soil productivity and on the quality of the environment in semi-arid regions of Saskatchewan. Report submitted to the Saskatchewan Agriculture, Food and Rural Revitalization. ADF Project 97000299 Res. 81BV.

Mooleki, S. P., Schoenau, J. J., Hultgreen, G., Wen, G. and Charles, J. L. 2002. Effect of rate, frequency and method of liquid swine manure application on soil nitrogen availability, crop performance and N use efficiency in east-central Saskatchewan. Can. J. Soil Sci. 82: 457-467.

Pastl, R., Hultgreen, G., Schoenau, J. J. and S. P. Mooleki 2000. Shallow injection of hog manure into grassland. Report submitted to the Saskatchewan Agriculture, Food and Rural Revitalization.

Qian, P. and Schoenau, J. J. 2000. Use of ion exchange membrane to assess soil N supply to canola as affected by addition of liquid swine manure and urea. Can. J. Soil Sci. 80: 213-218.

Schoenau, J. J., Mooleki, S. P., Qian, P. and Malhi, S. S. 2003. Balancing the availability of nutrients in manured soils. In 2003 Soils and Crops Workshop proceedings. Extension Division, University of Saskatchewan. [This issue].